II. *A Deſcription of an Engine to raiſe Water by the Help of Quickſilver, invented by the late Mr.* Joſhua Haskins, *and improv'd by* J. T. Deſaguliers, LL. D. R. S. S.

MR. *Haskins* finding that all Hydraulic Engines, working with Pumps, loſe a great deal of Water, (always giving leſs than the Number of Strokes ought to give according to the Contents of the Barrels:) and that when the Piſtons are new leather'd to prevent that Loſs, the Friction is much increas'd, and the Engines are ſubject to Jerks, which in great Works do often diſorder an Engine for a great while, by breaking ſome of the Parts; contriv'd a new way of raiſing Water without any Friction of Solids; making uſe of Quickſilver inſtead of Leather, to keep the Air or Water from ſlipping by the ſides of the Piſtons in the Barrels where they work; hoping thereby to prevent all the aboveſaid Inconveniences, and alſo to have Water Engines leſs liable to be out of Order than any yet made.

The firſt Experiment he made with an Engine that he ſet up at my Houſe about two Years ago, which I repeated before the Royal Society in a Model; and tho', by the ill Contrivance of the Parts, it did not raiſe near the Quantity of Water that the Invention is capable of; yet I ſhall deſcribe the Machine here, becauſe it will ſerve for the better Underſtanding of our preſent Engine.

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Fig. I.

dddd repreſents a *Lignum Vitæ* Plug or Piſton (which Mr. *Haskins* call'd a Plunger) about 6 Foot long made heavy enough with Lead at top to ſink into *Mercury*, which is beforehand pour'd into the Barrel D 1 D 2 up to *m m*. The Chain E 1 E 2, joyn'd to the Piſton and the Power that moves it, being let down till the Piſton comes to D 2, the *Mercury* riſes to the ſame Height in the Barrel, and in the Receiver R, (which it fills) namely to *n n*, as appears in the Figure. Then drawing up the Piſton till its Bottom is come to *m m*, the *Mercury* coming out of the Receiver down to *o o* makes a *Vacuum*, and the Weight of the Atmoſphere cauſes the Water to riſe up thro' the Sucking Pipe A 1 A 2, and Valve V into the Receiver where the *Mercury* was before. Upon letting down the Piſton again, the *Mercury* riſes into the Receiver, and drives up the Water thro' the Elbow B, the forcing Valve *u*, and ſo up the forcing Pipe *a* 2 *a* 1: But when once the forcing Pipe (which here was 46 Foot high) is full, before any *Mercury* can enter into the Receiver, and force any Water out at the top of the Pipe *a* 1, the *Mercury* between the Piſton and Barrel muſt riſe up to *q q* near 3 $\frac{1}{2}$ Feet above the Bottom of the Receiver, and as it continues to riſe up to *p p*, the Water is thrown out with a Velocity proportionable to the Height that the *Mercury* is rais'd above the 14th part of the Height of the Water. Now tho' the Friction of Solids is here avoided, it is plain that the *Mercury* muſt move from *m m* to *q q* without raiſing any Water, and that it can only force in going from *q q* to *p p*, and only ſuck in falling from *o o* to *m m*: And unleſs the Piſton is ſtopp'd a little

little while when at loweſt, the Water won't have time to run out: So likewiſe the Piſton muſt be ſtopp'd when at higheſt, that the Receiver may have time to fill.

Mr. *Haskins* likewiſe propoſed another Way, repreſented in *Fig.* 2; where the ſame Letters repreſent the ſame Parts, only here the Barrel is moveable by the two Chains E 1 E 2, and inſtead of a ſolid Piſton, the hollow Cylinder C 1 *cc* is fix'd, and the *Mercury* moving up and down in the lower Part of it, ſucks and forces the Water thro' the Elbow. The Figure repreſents the Engine ſucking, by means of the *Mercury* hanging from *o o* to *m m*. In order to force, before any Water can be driven out, the *Mercury* in the inner Cylinder muſt deſcend from *o o* to *m m*, and riſe up to *pp* between that Cylinder and the Barrel; ſo that here alſo a great deal of time is loſt; beſides the great Quantity of *Mercury* us'd, which is very expenſive; becauſe as much *Mercury* is mov'd every Stroke as the Water rais'd.

Theſe Difficulties very much puzzled Mr. *Haskins*, and quite diſcourag'd ſome other Perſons that had got the Secret of the Invention, and were ſetting up againſt him. But when I had conſider'd the Matter a little, tho' I had not time to contrive a Machine for it, I told him, That a little *Mercury* might be made to raiſe a great Quantity of Water, and there ſhould not be ſuch a loſs of time as in his Engines; but that I would have him find it out before I aſſiſted him farther. In a little time he found out the Contrivance repreſented in *Fig.* 4; and afterwards that of *Fig.* 3; which laſt was what I had thought of: And both theſe were alſo found out by the late Mr. *William Ureem*, who was an excellent Mechanick.

FIG. III.

Here the Barrel is mov'd as in *Fig.* 2, but the Plug *ddd* taking up a great deal of Space, there is Occaſion for no more *Mercury* than what will make a concave Cylinder or Shell up to *pp* between the Barrel D 1 D 2, and the hanging Cylinder C 1 C 2 *cc*, when the Stroke is made for forcing; and a concave Cylinder between the Plug and C 1 C 2 *cc*, when the Suction is made. I gave Mr. *Haskins* the Proportions for an Engine this way, of which he made a Draught, and ſhew'd it to the Right Honourable the Lord Chancellour about ſix Months ago. This I mention here, that no body may endeavour to get a Patent for this Invention, to the Prejudice of Mr. *Haskins*'s Aſſignees; who, ſince his Death, have deſir'd me to aſſiſt them in perfecting the Engine.

FIG. IV.

Here the Barrel with a third Cylinder *dddd* inſtead of the Plug of *Fig.* 3, is lifted up and down every Stroke, and the Water paſſes thro' *dddd*, the *Mercury* making a Shell ſometimes between the middle and inner Cylinder, as in the Suction; and ſometimes between the Barrel and the middle Cylinder, as in the forcing Stroke.

Mr. *Haskins* had contriv'd ſuch a Machine as is repreſented by this 4th Figure, and beſpoke the ſeveral Parts before he dy'd; and therefore when I was deſir'd by his Aſſignees to direct the ſetting up the Machine, I was oblig'd to make uſe of the Pieces already made, in order to ſave the Expence of a new Engine: And now the whole put together with ſome

Alterations, make the Engine repreſented by *Fig.* 5, as it is ſet up at my Houſe in *Weſtminſter*, and by the Force of one Man, raiſes a Hogſhead of Water in little more than a Minute and a half to the Height of 27 Feet. All the Fault of the Machine of *Fig.* 5 is, that the Pendulum Handle *Ff* is too long, and the Bottom of the middle Cylinder C ought to be juſt in the middle of the Height to which the Water is to be rais'd, ſuppoſing three Copper Cylinders to be as they are here: If likewiſe the Barrel D 1 D 2 work'd under the forcing Pipe, the Lift would be eaſier. Therefore I deſcribe the Machine with the ſmall Alteration repreſented in *Fig.* 6.

The ſucking and forcing Pipe and Valves are mark'd with the ſame Letters as in the other Figures; and the Chains E 1 E 2 muſt be ſuppos'd to hang from ſuch Pullies, and to be mov'd by ſuch a Pendulum as is in *Fig.* 5. The Barrel D 1 D 2 (call'd otherwiſe the outer Cylinder, and repreſented by the ſame Letters in *Fig.* 7,) has within it another Cylinder (call'd the inner Cylinder or Plug, as *dddd Fig.* 7,) between which two Cylinders a certain Quantity of *Mercury* is pour'd in, and the hanging Cylinder C coming down into the *Mercury*, a Stroke of 13 Inches may be made by the Motion of the Barrel, which, in going down ſucks by making a *Vacuum* in C, and in going up forces the Water out of the top of the forcing Pipe, performing the Office of a common Piſton; only that inſtead of Leather to make it tight to the Cylinder C, there is always a thin Shell of Quickſilver either between the middle Cylinder C and the inner one, *(dddd Fig.* 7.) as happens when the Suction is made, or between the middle and outer Cylinder, as happens in lifting up the Barrel to Force. In the Suction, the *Mercury* is higher in the inner Shell than in the outer Shell, by an Height equal to a little more than $\frac{1}{14}$ Part of the Height of the Barrel above the Water to be rais'd: And in forcing, it is higher in the outer Shell than in the inner by a little more than $\frac{1}{14}$ of the Height of the Pillar of Water to be forc'd. And therefore if the Water is not required to be rais'd above 64 Feet, the Barrel ſhould move ſo as to make the Middle of its Stroke at the Height of 30 Feet, or at the middle of the way from the Water to be rais'd, to the Delivery at top.

The 7th Figure drawn by a larger Scale, repreſents the three Cylinders, which are here made of Copper in their juſt Proportions: And for the ſake of thoſe that would conſider this matter fully, I have here given their Lengths, Diameters within and without, and Thickneſs.

	Outer Cylinder or Barrel, D1 D2.	Middle or hanging Cylinder, in which the Stroke is made C1 C2 *cc*.	Inner Cylinder or plug cloſed at top by a Cap, and moving up and down with the Barrel to which it is joyn'd at bottom. *dddd*.
	Inches	*Inches*	*Inches*
Length	30	29,0	31,2
Diameter within.	6,74	6,35	6,03
Thickneſs	0,10	0,08	0,13
Diameter without	6,94	6,51	6,29

Here B B repreſents part of the Elbow of *Fig.* 5. or of the forcing Pipe of *Fig.* 6. But as the Spaces between the Cylinders are ſo ſmall, as not to be viſible even in a large Draught made by a Scale; I have here given three more Draughts of the three

Cylinders, where the Height is agreeable to the Scale of the 7th Figure, but the Diameters of the middle and inner Cylinders are made leſs than they are in the Engine, to make the Space between (where the *Mercury* riſes and falls) viſible; and the Cylinders themſelves are repreſented by ſingle Lines.

The Quantity of *Mercury* us'd in this Engine is 36 ½ Pounds, which being pour'd in between the outer and inner Cylinder, riſes up to the Height of 16. Inches.

When the Barrel is pull'd up (as in *Fig*. 9,) ſo as to have the middle Cylinder within an Inch of the Bottom of the Barrel; the *Mercury* on both ſides the middle Cylinder will riſe up to the Height of 23,1 Inches, that is about two Inches below the Cup D1, to the Line *q q*.

When the Barrel is going down to fill the ſucking Pipe and middle Cylinder C, the *Mercury* in the inner Shell will be 25 Inches high, and only 13 in the outer Shell, *Fig*. 9, where the ſhaded part repreſents the ☿.

At the End of the ſucking Stroke the *Mercury* is up to the top of the inner Cylinder, and ſcarce an Inch in the outer Shell. *Fig*. 8.

In raiſing the Piſton from forcing to Sucking, the firſt 1 ¼ Inch drives the *Mercury* out of the inner Shell, and raiſes it in the outer Shell 13,28 Inches.

The Depth of an Inch of Water in the middle Cylinder above the inner one or Plug is equal to a Space in the outer Shell of 13,28 Inches, and ¼ of an Inch is equal to the ſame Height in the inner Shell.

Therefore when the *Mercury* is equally high in both Shells, a Motion of ¼ of an Inch of the Barrel will charge for Suction. That is, upon letting down the Barrel only ¼ of an Inch, the Preſſure of the Atmoſphere in the outer Shell will raiſe the *Mercury* in the inner one 13,28 Inches, at the ſame time, that it puſhes up the Water from the Well 13 Foot and a half high into the ſucking Pipe. And when all the Pipes are full, if the *Mercury* be equally high in both Shells, upon raiſing the Barrel one Inch, the *Mercury* will riſe 13,28 Inches in the outer Shell; which I call charging for forcing; becauſe in continuing to raiſe the Barrel, the forcing Valve immediately riſes, and the Water comes out at top during the reſt of the Stroke, which is 12 Inches, and delivers 1,6 Gallon of Water, Wine Meaſure.

Fig. 10. repreſents the forcing Stroke half way up; with the ☿ 17 Inches in the outer Shell 4 Inches in the inner, and the whole ſpace at bottom under the middle Cylinder 7 Inches.

From this it appears, that in the whole Stroke of 13 Inches in Length, there is only $\frac{1}{4}$ of an Inch loſt to charge for Suction, and in the next ſtroke, which is likewiſe of 13 Inches there is only one Inch loſt to charge for forcing; ſo that in a Motion of 26 Inches, there is but 1 $\frac{1}{4}$ Inch, or about $\frac{1}{20}$ part ineffectual. But this is owing to the too large ſpace of the outer ſhell, which contains 4 times more than the inner one, becauſe the Cylinders were only hammer'd, and not turn'd; for if the outer ſpace had been no bigger than the inner, then $\frac{1}{4}$ of an Inch of the ſtroke would have charg'd for forcing; ſo that only $\frac{1}{2}$ an Inch in 26, or $\frac{1}{52}$ part of the whole ſtroke would have been ineffectual; and in that Caſe, $\frac{2}{5}$ of the Quantity of *Mercury*, or a little more than 12 Pounds, would have been ſufficient.

There may ſtill leſs *Mercury* be us'd, if the middle Cylinder be made of Plate Iron turn'd on the outſide, and bor'd within, the outer Cylinder bor'd, and the inner one turn'd; ſo that if the Work be well perform'd, eight or ten Pounds of *Mercury* will be be ſufficient in this Engine, tho' the Bore of the middle Cylinder, or Diameter of the Pillar of Water which is rais'd, be of 6,35 Inches. If the Bore of the ſaid Cylinder was but 3 Inches, leſs than 3 Pounds of Mercury would ſuffice, and leſs than ſix if there were two Barrels, in order to keep a conſtant ſtream thro' a Pipe of almoſt the ſame Diameter. This will very much leſſen the Expence of Mercury, which would otherwiſe be an Objection againſt this Engine; and by making the inner and outer Cylinder of hard Wood, as *Box*, or *Lignum Vitæ*, the Coſt of the Engine may ſtill be reduc'd. But if the Engine be very large, Caſt Iron bor'd will be proper for the outer Cylinder, and Caſt Iron turn'd on the outſide for the inner Cylinder or Plug, and hammer'd Iron bor'd and turn'd for the middle Cylinder.

There is an Objection, which ſeems at firſt to take off the intended Advantage of this Engine, which is this, *viz.* That inſtead of the Friction of the Leather of a Piſton, when we lift up our Barrel to force, the Reſiſtance, that the *Mercury* finds to riſe in the outer Shell, is at leaſt as great as the Friction that we avoid. Now that Reſiſtance is never greater than the Weight of a concave Cylinder of *Mercury*, whoſe Height is the greateſt to which the *Mercury* riſes in the ſaid Shell, and the Baſe is the Area of the Shell it ſelf. This Weight in our Engine is equal to 57,5 Pounds, and therefore one would think it greater than the Reſiſtance made by the Friction of a Piſton. But if it be conſider'd, that in the Deſcent of the Barrel for ſucking, the *Mercury* ſhifts immediately into the inner Shell, riſing to the ſame Height, and ſtill keeping the ſame Baſe; the aforeſaid Weight of 57,5 Pounds helps down the Barrel, and facilitates the overcoming of the Force of the Atmoſphere, conſequently the

Weight of the *Mercury* being balanc'd, is no Hindrance, whether you work with a ſingle or a double Barrel.

There remains only then the Hindrance by loſs of time in the Beginning of any Stroke: But I have ſhew'd that to be but $\frac{1}{52}$ part of the ſtroke. I have found that the beſt Engines now in uſe generally loſe near $\frac{1}{5}$ of the Water that they ought to give, according to their Number of Strokes. And Mr. *Henry Beighton*, an ingenious Member of this Society, having a great many times meaſur'd the Water that is rais'd by Engines in Mines, found that ſome Engines loſt $\frac{1}{4}$, and none ever loſt leſs than $\frac{1}{5}$ of what they ought to give according to the Number of the Strokes in their Pumps, whatever auxiliary Powers they were mov'd with.

There is indeed another Objection, but ſcarce worth notice; which is, that ſome Particles of *Mercury* will mix with the Water that is rais'd, and make it unwholeſome; but no body that conſiders Specifick Gravity, will imagine any ſuch thing. However, to ſatisfie thoſe that might ſtill apprehend it, it is to be obſerv'd, that none of the Water that is rais'd comes near the Mercury: For in the Cylinder C, and part of the Elbow B, (*Fig.* 5.) there is always above the Mercury a certain Quantity of Water that riſes and falls with the Barrel, and never goes into the forcing Pipe. The ſame happens alſo in the Machine of *Fig.* 6. for the Water having once run into the Cylinder C, all that is rais'd afterwards, comes thro' the forcing Valve without coming down to the Mercury.

Provided Care be taken to make the Barrel with its Plug tight, I don't ſee that this Machine will want Repair in a long time, except ſome of the auxiliary Powers be out of order, which do not relate to this

this Invention. The Numbers given will ſerve to examine the Truth of what I have aſſerted concerning the Motion of the Mercury: And from them one may make Tables to ſerve to proportion theſe Engines for raiſing any Quantity of Water to any Height, according to the Power one has to apply.

III. *Part of a Letter from Mr.* Peter Derante, *Chirurgeon in* Waterford, *to Mr.* John Douglas, *Chirurgeon, F. R. S concerning the coming off of the* Scapula *and Head of the* Os Humeri, *upon a Mortification.*

ON the 5th of *November*, 1713, One *John Fletcher*, on board the *Neptune* of *Leverpool*, had the Misfortune to break the *Radius* and *Ulna* (of his left Arm) and their Ends burſt thro' the Skin. He was immediately dreſs'd by the Surgeon of the Ship with the common Aſtringents and Bandage; about five or ſix Days afterwards I was ſent for to go down to *Paſſage* to ſee this Man. When I came there, I found his Surgeon along with him, who told me, That the Man would do very well, becauſe he was in no pain at all; however, I deſir'd him to take off the Dreſſings, and let me look on't. Which being done, I found it was black and inſenſible from his Fingers to his Shoulder, and therefore adviſ'd the Extirpation of it immediately, but his Surgeon oppoſ'd it; however, I ſcarified it in ſeveral Places, and very deep, and then apply'd a warm Dreſſing. Next Day the Ship put to Sea, and the poor

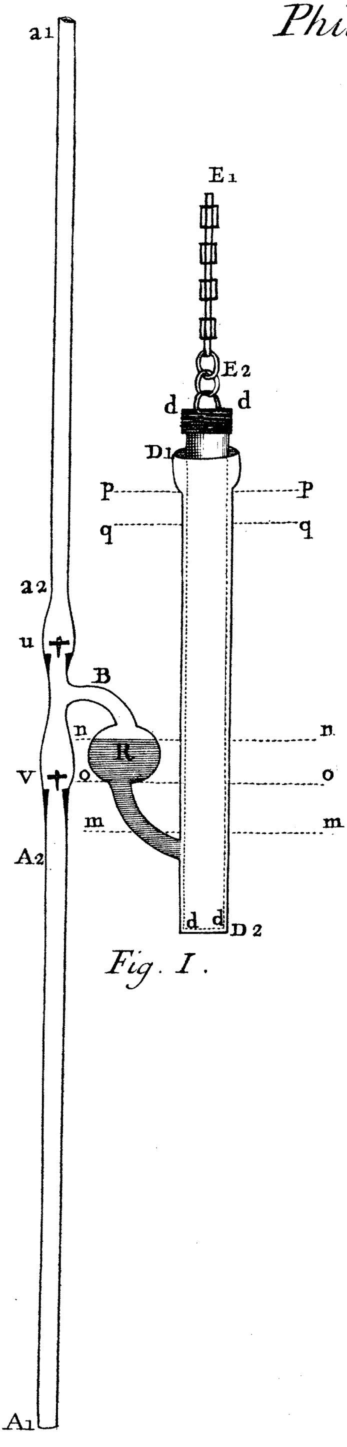

Fig. I.

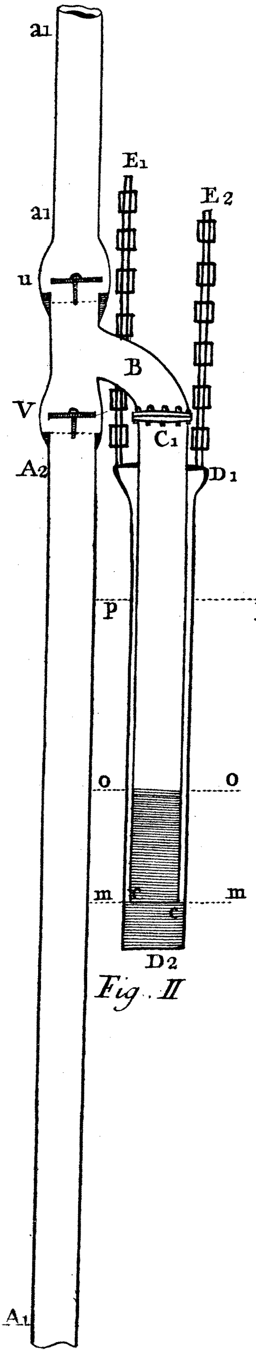

Fig. II

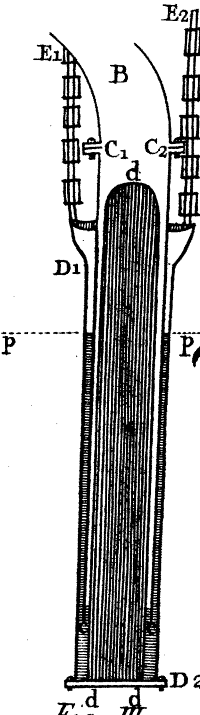

Fig. III

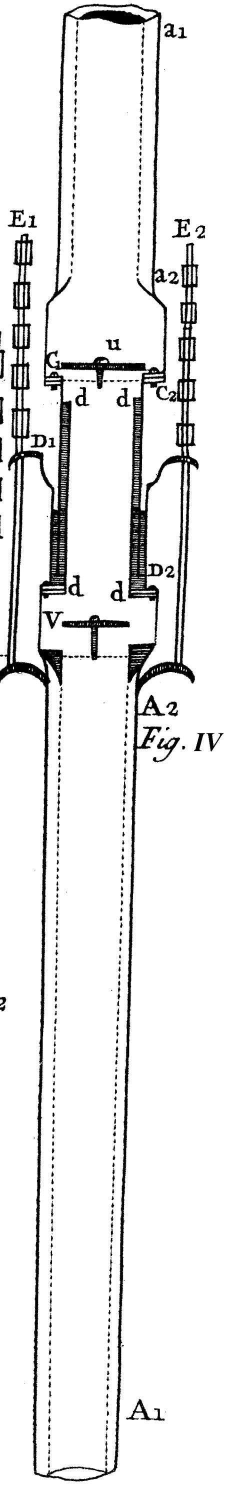

Fig. IV

	Inner Cylinder.	2d or Mid. Cylinder.	Outd Cylinder
	feet Inch.s tenths	f. i. t.	f. i.
Length	2 . 7 . 2	2 5 . 0	2 . 6
Diameter within	0 . 6 . 03	6 . 35	
Thickneſs	0 . 13	0 . 08	

Distance betwen Outer & Inner Cylinder 0.225

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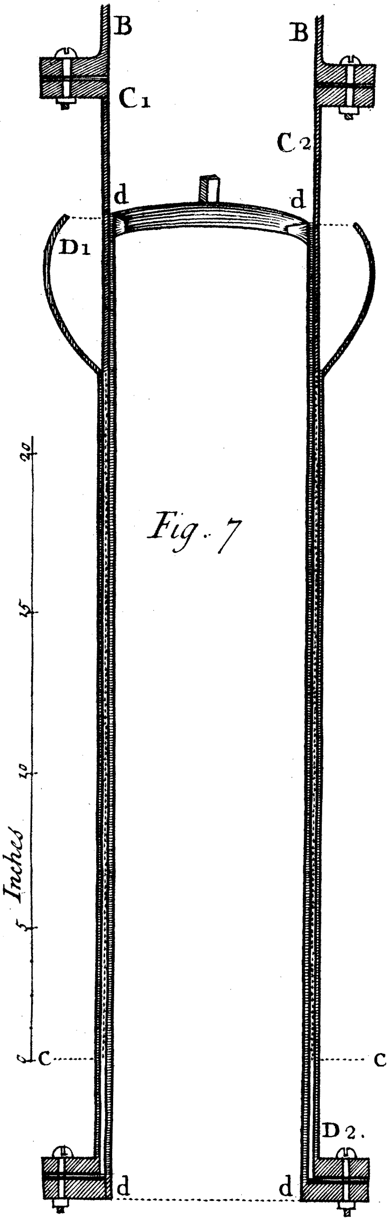


Fig. 7

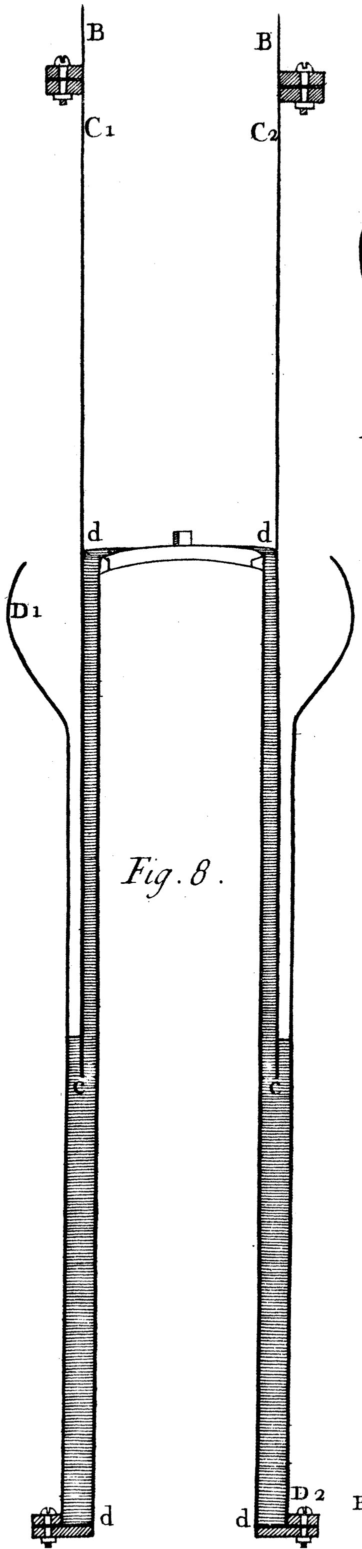


Fig. 8.

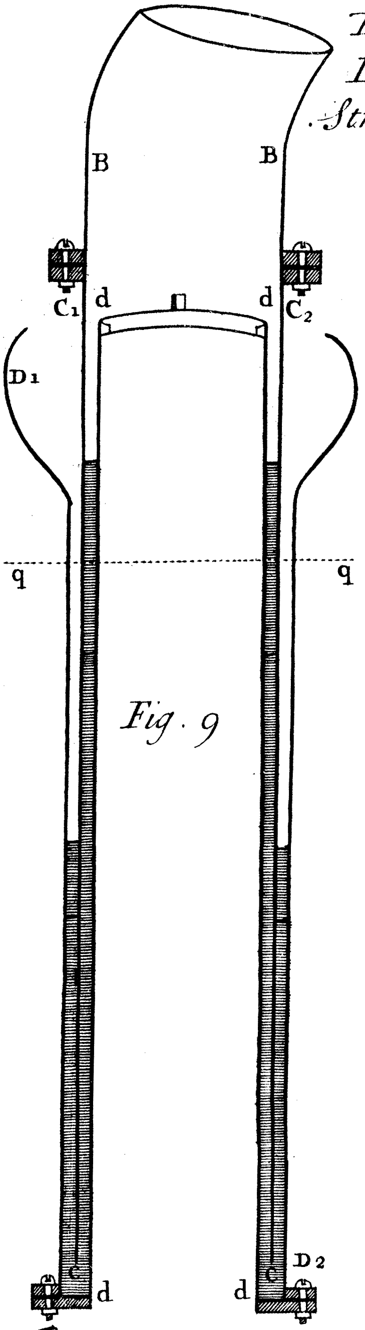
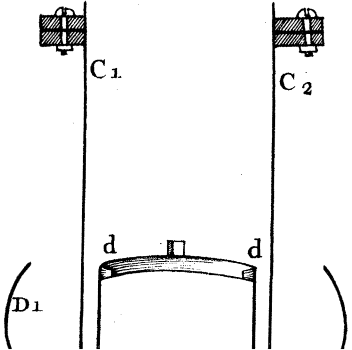
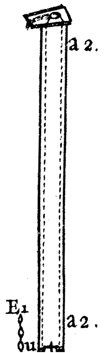
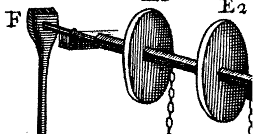


Fig. 9







oth of the Cup 5 Inches
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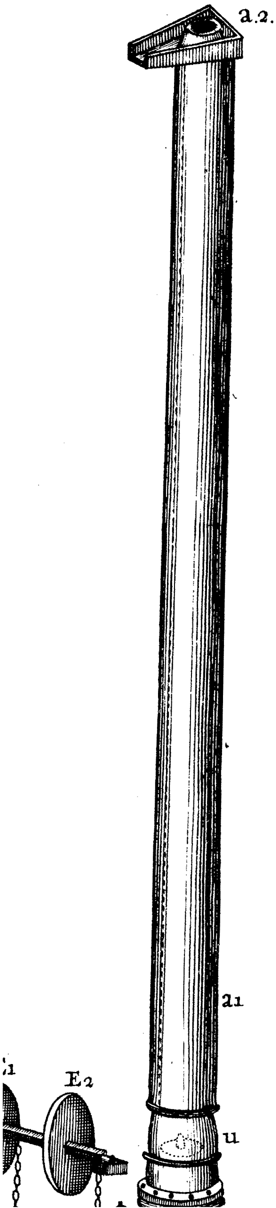


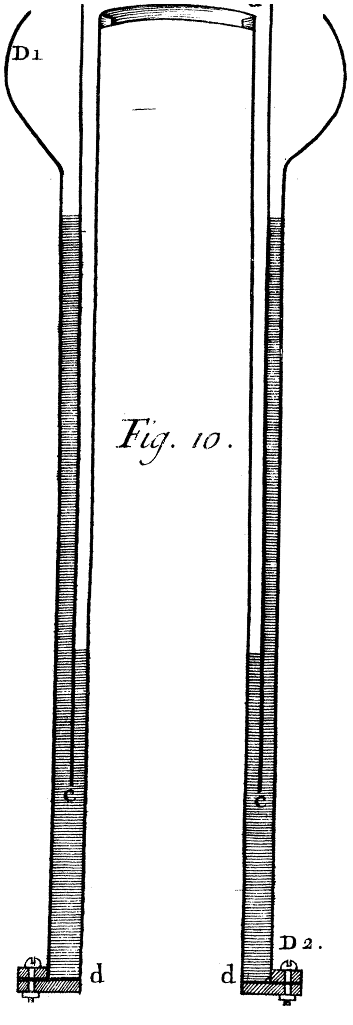
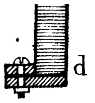
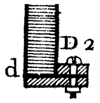


Fig. 10.





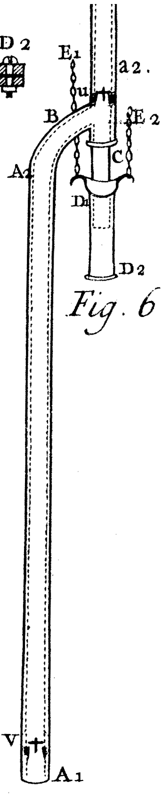


Fig. 6

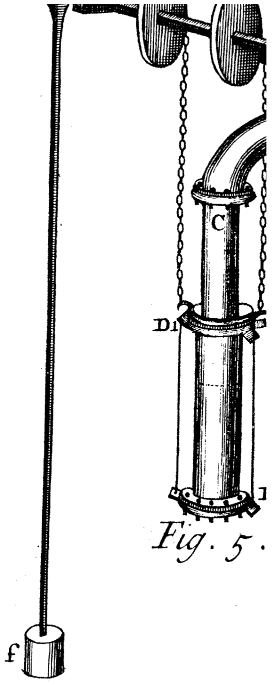


Fig. 5.

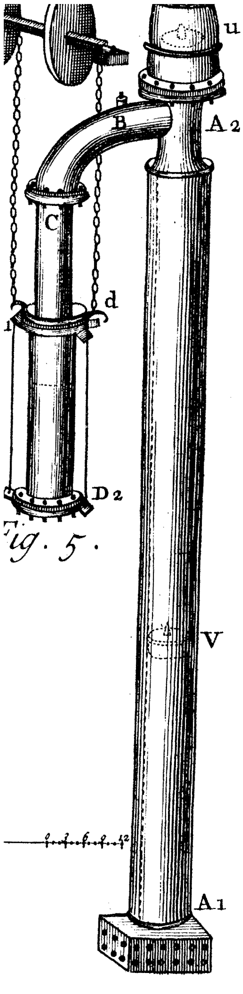


Fig. 5.

	Inner Cylinder. feet Inch. tenths	2d or Mid. Cylinder. f. i. t.	Out. Cylinder f. i.
Length	2 . 7 . 2	2 5 . 0	2 . 6
Diameter within	0 . 6 . 03	6 . 35	
Thickneſs	0 . 13	0.08	

Distance betwen Outer & Inner Cylinder 0.225

Depth of the Cup 5 Inches
Diameter 10.5
Length of Pendulum 9 foot
Stroke in ye Cylinder 13 Inches

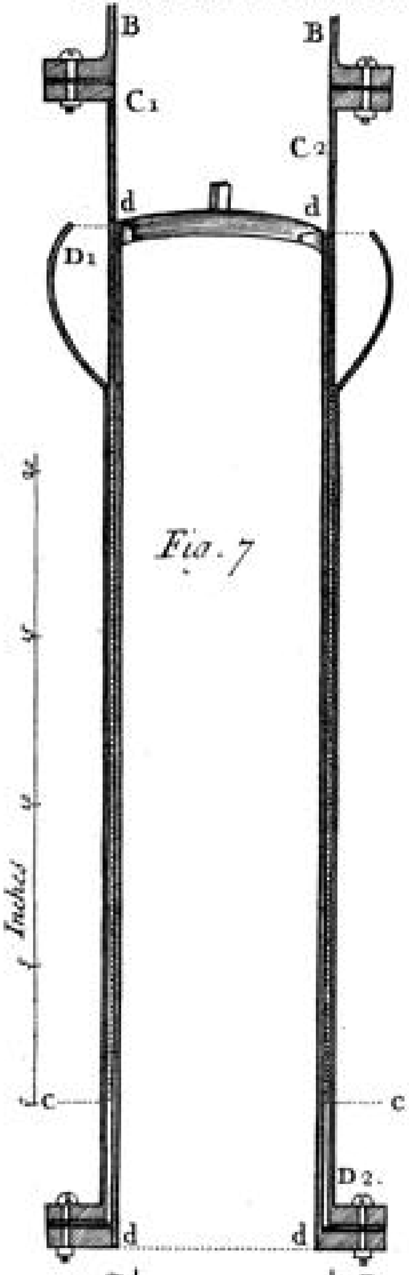
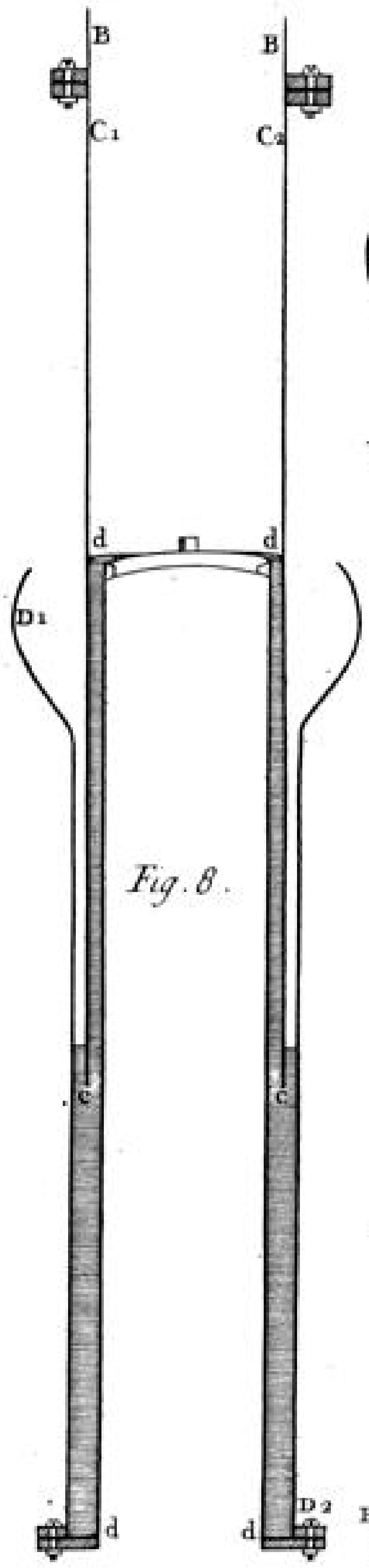


Fig. 7.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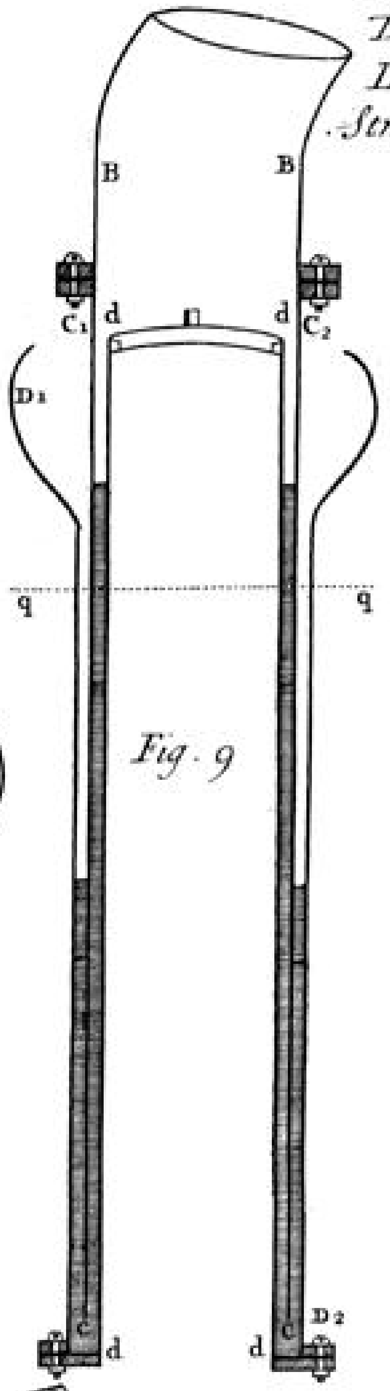
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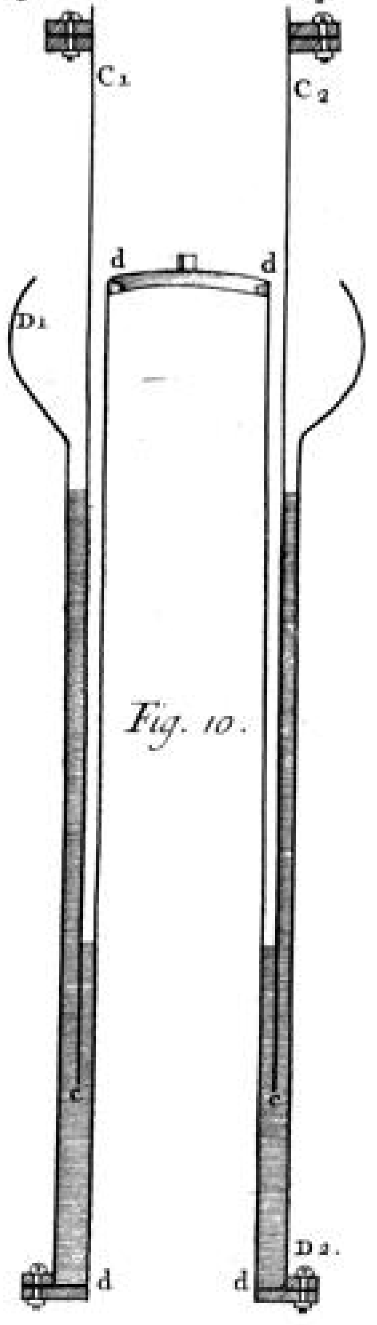
Fig. 10.

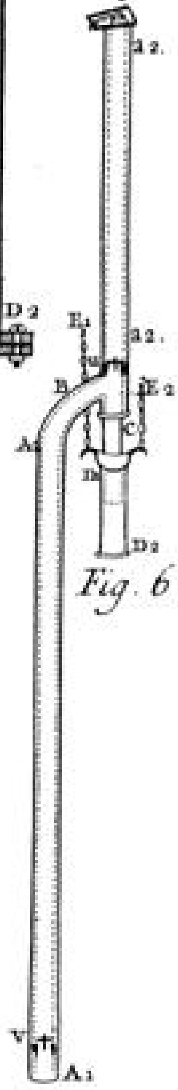
Fig. 6.

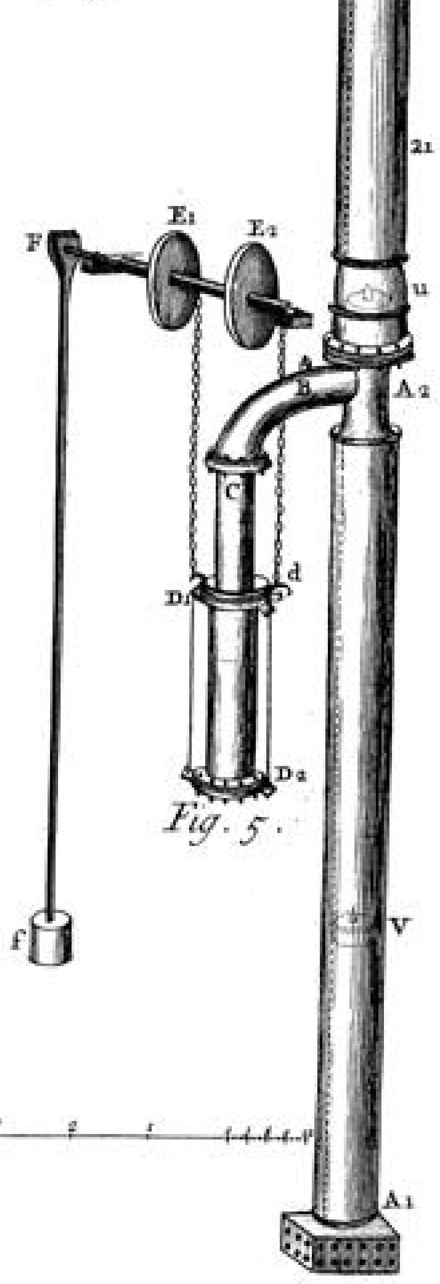
Fig. 5.